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FEDERAL COMMUNICATIONS COMMISSION
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FEDERAL COMMUNICATIONS COMMISSION
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In the Matter of

The Establishment of Policies and
Service Rules for the Non-Geostationary
Satellite Orbit, Fixed Satellite Service
in the Ku-Band

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IB Docket No. 01-96

COMMENTS OF SKYBRIDGE

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SUMMARY

In the instant NPRM, the Commission explores various frameworks for facilitating sharing among multiple NGSO FSS systems in the Ku-band. “Option III” outlined by the Commission, which is based on avoidance of “in-line” interference events, is the only method proposed that meets all of the objectives articulated by the Commission in the NPRM. The other methods, based on either band segmentation or use of homogeneous constellation design, suffer from numerous problems that would impede rapid introduction of innovative services.

The options based on band segmentation do not guarantee licensees access to sufficient spectrum to support economically-viable operations. Moreover, they introduce a degree of uncertainty regarding the availability of bands, which may impose undesirable design constraints on the systems. Finally, by giving operators exclusive rights to spectrum vis-à-vis other NGSO operators, and by discouraging use of interference mitigation techniques, these methods also impede development by operators of more spectrum-efficient coordination agreements.

The options based on use of homogeneous constellations take critical business decisions away from the operators, and place them in the hands of the Commission. Requiring applicants to employ a “government-approved” constellation would thwart the business plans of many of the applicants. In particular, the orbit proposed by Virtual Geo would require SkyBridge to sacrifice interactivity and transparency to standard internet protocols, two of its key technical and business objectives.

Finally, because both of these options remove incentives for operators to implement interference mitigation capabilities, they would place the U.S.-licensed systems at a distinct disadvantage when serving regions or countries that have adopted alternative sharing regimes. These systems may not be able to meet the burden of sharing with foreign-licensed systems operating according to a different framework.

Option III, on the other hand, solves all of these problems. By taking advantage of the antenna discrimination inherent in all of the proposed NGSO FSS system designs, it permits each constellation to use all of the allocated spectrum during a great portion of the time. Moreover, the steps taken to reduce interference during “in-line” events between two or more satellites affect only those satellites; other satellites (and systems) may continue to use the entire band. At the same time, Option III does not require any of the applicants to depart from their proposed constellation designs, which allows the market, instead of the Commission, to dictate the services that are offered.

Furthermore, the technique offers full regulatory certainty. The Commission need not involve itself in administration of the regime once the framework is specified. At the same time, it encourages the operators to coordinate among themselves to achieve even greater spectrum efficiency.

Finally, it places the U.S.-licensed systems in an excellent position to provide service in foreign countries, no matter what sharing regime is employed by other administrations. Because the option inherently provides incentives for incorporation of mitigation techniques into systems, these capabilities can be put to use to share with foreign systems.

In sum, Option III provides each entrant equal access to the available spectrum, without requiring permanent and systematic reduction of the available spectrum to each operating NGSO FSS system, as in the options based on band segmentation. Furthermore, the option does not require operators to make fundamental system design changes that would sacrifice their technical and business plans, as in the case of enforced homogeneity. For these reasons, Option III is the only option that meets every one of the Commission's stated objectives in this proceeding, and SkyBridge urges the Commission to proceed expeditiously to implement it.

TABLE OF CONTENTS

	PAGE
SUMMARY	i
TABLE OF CONTENTS	iv
I. INTRODUCTION	2
II. SPECTRUM SHARING OPTIONS.....	5
A. Option I – Flexible Band Segmentation	6
B. Option II – Dynamic Band Segmentation	9
C. Option IV – Homogeneous Constellations.....	10
1. General Considerations.....	10
2. Virtual Geo Proposal	13
D. Option III – Avoidance of In-Line Interference Events	16
1. General Considerations.....	16
2. Implementation	18
III. EARTH STATION LICENSING	21
A. Blanket Licensing of User Earth Stations.....	21
B. NGSO FSS User Earth Station Antenna Patterns	22
C. NGSO FSS Earth Station Off-Axis e.i.r.p. Limits.....	22
IV. SERVICE RULES	23
A. Coverage Requirement	23
B. Financial Qualifications	23
C. Implementation Milestones	24
D. Demonstration of Compliance with Aggregate EPFD _{down} Limits	25
E. Demonstration of Compliance with Single-Entry EPFD _{down} Limits	26
F. International Coordination	28
G. System License and License Terms.....	29
H. Regulatory Classification.....	29
I. Reporting Requirements	30
J. Orbital Debris Mitigation	30
K. Sale of License.....	30
CONCLUSION.....	31
ANNEX I	

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COMMENTS OF SKYBRIDGE

SkyBridge L.L.C. ("SkyBridge"), by its attorneys, hereby submits its comments on the Notice of Proposed Rulemaking ("NPRM") in the above-captioned proceeding.¹ This proceeding will develop the service rules for non-geostationary satellite orbit ("NGSO") Fixed-Satellite Service ("FSS") systems in the Ku-band, including the rules for frequency sharing among the multiple applicants for such systems.² SkyBridge has previously commented on many of these issues in related proceedings.³

¹ FCC 01-134, rel. May 3, 2001 (the "NPRM").

² Many of the technical rules for these systems, including the requirements for protecting other co-frequency services, were already adopted in the Commission's First Report and Order and Further Notice of Proposed Rulemaking in ET Docket No. 98-206, RM-9147, and RM-9245, released December 8, 2000 (the "Report & Order").

³ With respect to the service rules for NGSO FSS systems, see, e.g., In the Matter of Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems in the Ku-Band, ET Docket No. 98-206, RM-9147, and RM-9245, Comments of SkyBridge, March 2, 1999 ("SkyBridge NPRM Comments") and Reply Comments of SkyBridge, April 14, 1999 ("SkyBridge NPRM Reply Comments"), SkyBridge Petition for Reconsideration, March 19, 2001 ("SkyBridge Petition for Reconsideration"). See also In re applications of The Boeing Company, File No. SAT-AMD-19980108-00006 et al., Comments and Consolidated Petitions to

I. INTRODUCTION

In the NPRM, the Commission articulated a number of objectives for the NGSO/NGSO sharing framework. In particular, the Commission stated that the adopted rules should:

- "expedite the authorization process;"⁴
- "provide incentives for prompt commencement of service to the public using state-of-the-art technology;"⁵
- "provide regulatory certainty to the NGSO FSS licensees;"⁶
- provide adequate business certainty to support an economically viable license;⁷
- permit the Commission to "license all applications on file in this service;"⁸
- "ensure that all applicants have equal access to spectrum;"⁹

Deny and/or Hold in Abeyance of SkyBridge L.L.C., June 30, 1999 ("SkyBridge Petitions to Deny") and Reply of SkyBridge L.L.C., August 16, 1999.

With respect to NGSO/NGSO sharing regimes, see, e.g., Ex Parte Presentation of SkyBridge, "Methods for sharing between NGSO systems in the Ku-band," November 8, 2000; Ex Parte Presentation of SkyBridge, "Co-Frequency Sharing by NGSO FSS Systems in the Ku-band," November 30, 2000; Ex Parte Presentation of SkyBridge, "NGSO/NGSO Sharing," February 28, 2001; and Ex Parte Presentation of SkyBridge, "Implementing 'Home Zone' as a Default Solution for Ku-Band NGSO/NGSO Sharing," March 27, 2001. See also In the Matter of Applications of SkyBridge L.L.C., File No. SAT-AMD-19990108-00004, et al., Motion for Expedited Licensing, July 20, 2000.

⁴ NPRM, ¶ 1.

⁵ Id.

⁶ Id., ¶ 19.

⁷ Id., ¶ 20.

⁸ Id., ¶ 1.

⁹ Id., ¶ 17.

- "promote competition through opportunities for new entrants;"¹⁰
- "prevent spectrum warehousing by non-implemented NGSO FSS systems at the expense of operational systems;"¹¹
- provide sufficient spectrum capacity for each system;¹²
- "not . . . preclude, in any way, the NGSO FSS systems' coordinated use of their spectrum assignments;"¹³
- achieve "an outcome dictated by the service market rather than by regulatory decision;"¹⁴
- establish a "regulatory framework that does not favor any particular technology or operational method;"¹⁵ and
- "avoid the addition of duplicative and unnecessary rules."¹⁶

SkyBridge agrees with all of these goals. It is vital to the future of these important NGSO projects that they be licensed as soon as possible. Licensing will provide investors much-needed assurance of the Commission's commitment to facilitating deployment of Ku-band NGSO FSS systems. It will immediately provide increased credibility for the proposed projects, thereby fostering allocation of funds and execution of contracts. It will eliminate one of the key hurdles facing NGSO FSS

¹⁰ Id., ¶ 1.

¹¹ Id., ¶ 18.

¹² Id., ¶ 20.

¹³ Id., ¶ 19.

¹⁴ Id., ¶ 3.

¹⁵ Id., ¶ 16.

¹⁶ Id., ¶ 4.

proponents in the marketplace, and permit the Commission's goal of multiple, competing broadband services to be realized.

SkyBridge agrees with the Commission that its adopted framework for sharing should ensure that all systems can potentially be accommodated, and should give all of the applicants in the instant processing round an equal opportunity to launch and operate their systems. In particular, the solution must ensure that early entrants cannot thwart the ability of later systems to launch, while at the same time protecting against warehousing of spectrum. The sharing solution adopted also should be as generic as possible, so as not to confer a competitive advantage on any of the systems.

The rules must also be consistent with the fact that all of the proposed systems require far more bandwidth than would be available with a simple segmentation of the allocated bands.¹⁷ Co-frequency sharing among the systems is therefore necessary to ensure the commercial viability of the systems. The sharing framework should facilitate, and indeed provide incentives for, individual coordination among the operators.¹⁸ At the same time, it must also provide a reasonable "default" solution that would govern sharing should systems for any reason be unable to achieve coordination

¹⁷ Capacity is strongly related to bandwidth; thus the amount of spectrum available to each system is a key element in the commercial viability of the systems. As discussed below, band segmentation to accommodate all the applicants would have a catastrophic impact on the commercial viability of the systems.

¹⁸ Coordination among applicants is the optimal method for sharing. As opposed to imposition of a generic sharing regime, coordination can take into account the specific features and flexibilities of each system, and thereby produce solutions that maximize capacity and minimize burdens for each system. Moreover, coordination permits the operators to maintain an equitable balance of constraints among the systems. However, the applicants in this proceeding appear to be at dramatically different stages in the design and development of their respective systems. Therefore, the Commission's solution cannot depend on the expeditious development of a coordination agreement among all of the applicants.

agreements. The default solution should be simple and self-implementing, to avoid the need for the Commission to micro-manage the operation of the systems, but it must also guarantee each system sufficient spectrum to operate an economically-viable system.

SkyBridge urges the Commission to adopt rules that reflect the fact that each of the NGSO applicants has selected a different constellation design, each of which is tailored to the particular market that the operator wishes to serve. Some, like SkyBridge, have chosen low earth orbit ("LEO") systems in order to minimize transmission delay and maximize interactivity. Others have chosen higher altitude systems, such as medium earth orbit ("MEO") and high earth orbit ("HEO"), to maximize the coverage area of each satellite. These differences reflect legitimate business decisions, which the Commission's rules should not unduly thwart. For these reasons, the sharing framework should be technology neutral; i.e., it should neither favor any particular design, nor should it require any operator to make system changes that would materially impact the fundamental characteristics of its system or proposed services.

II. SPECTRUM SHARING OPTIONS

The Commission has proposed four alternative frameworks for NGSO/NGSO sharing. As discussed below, while each of the proposals has certain advantages and disadvantages, only Option III squarely meets all of the Commission's stated objectives in this proceeding. The other options suffer from a number of flaws. Chief among these, they: (1) fail to provide licensees certainty that they will have access to sufficient spectrum to support broadband services; (2) minimize or eliminate opportunities for more efficient coordination; and (3) impose design constraints on the systems that would adversely affect provision of innovative services.

A. Option I – Flexible Band Segmentation

Option I detailed in the NRPM would assign to each NGSO licensee a portion of spectrum for its exclusive use (vis-à-vis the other NGSO licensees). The available spectrum would be divided by the Commission into segments according to the number of applicants.¹⁹ Assuming N licenses, each system would have access to a 1/N of each of the available sub-bands.²⁰ Each licensee would select an available segment when it begins to launch its satellites. However, operating constellations would be permitted to employ unoccupied spectrum reserved for other NGSO FSS systems, provided that the operating constellations could coordinate their use of these unoccupied bands.²¹

¹⁹ SkyBridge agrees with the Commission that it should ensure that "all NGSO FSS systems . . . have access to some spectrum in each of [6] sub-bands." NPRM, ¶ 17. As SkyBridge has explained in previous filings, equality requires that the sharing framework take into account the non-fungibility of the Ku-band. All portions of the available spectrum are already used for different services, creating different interference environments in each of the sub-bands. The Commission's proposal to ensure that its sharing solution provides each applicant access in each of the six sub-bands identified in the NPRM is necessary to guarantee that each system has equal access to the spectrum.

²⁰ The number "N" will depend on a number of considerations. Although there are seven applications for U.S.-licensed systems in this proceeding, there are only six applicants. As SkyBridge has previously pointed out, the "two-part constellation" proposed by Hughes Communications Inc. in its two applications should rightfully be considered as a single system, to avoid defeating the fundamental premises of the internationally- and domestically-adopted power-flux density limits. See SkyBridge Petitions to Deny at 32. In addition, other applications, in their current form, would not comply with all of the Commission's proposed service rules, such as coverage requirements. Finally, it remains to be seen whether all of the applications can meet the various requirements to protect, inter alia, GSO FSS, GSO BSS, FS, and Radiolocation systems. The final number "N" will therefore not be determined until after the Commission adopts all of the rules for these systems and applies those rules to the various applications, including amendments thereto.

²¹ NPRM, ¶ 23.

While this proposal would be simple to implement and, for the most part, treats all licensees equally, it fails to meet several of the most important Commission goals summarized above. First, it would fail to provide adequate business certainty because it does not guarantee sufficient spectrum capacity for each system. The broadband services proposed by the applicants in this processing round require far more than $1/N$ of the spectrum available, and would not be economically viable with such limited bandwidth.²² Although, under the Commission's proposal, additional spectrum *may* be available to individual licensees, there is no assurance that this will be the case. Moreover, the availability of this unused spectrum will decrease over time, as new systems enter service. Thus, at precisely the point at which the earliest entrants are beginning to load their systems to full capacity, they will face a reduction in available bandwidth. This situation creates substantial business uncertainty that can significantly inhibit the financing of these systems.

Moreover, the proposal could easily thwart efficient use of the spectrum, by hindering coordination among NGSO FSS systems, which could yield far greater capacity from the limited spectrum. This is because, depending on the design of its system, an operator could have a strong disincentive to allow sharing of its exclusive spectrum and/or the unused spectrum, even if such sharing is technically feasible and would not unduly hinder its own operations. Granting exclusive spectrum rights to individual operators is simply an invitation to those operators to protect those rights. Moreover, considerations such as business competition could encourage a system not to

²² Although, as noted above, the number "N" cannot be determined at this time, assuming the Commission allows the current applicants to amend their applications to come into compliance with all technical and service rules applicable to such systems, the ultimate number is likely to be at least six.

coordinate with another system to permit use of unused spectrum.²³ Maximum use of the spectrum could only be achieved if all of the operators have an incentive to agree not to exercise their exclusivity rights and instead agree to coordination.

Furthermore, this proposal is not technology neutral, and would impose specific requirements on systems that hope to employ more than $1/N$ of spectrum. Such systems would have to be built to operate over greater bandwidths than they may ever be permitted to use, while still remaining capable of operation within any given $1/N$ of the spectrum. In other words, two very different modes of operation would have to be planned for, due to the regulatory uncertainty inherent in Option I. Such systems would have to be capable of frequency diversity,²⁴ so that they could adapt to repeated changes in frequency plans. Even operators that redesigned their systems and business plans to operate in only $1/N$ of the spectrum would have to be prepared for the possibility that, by the time they launch, another system will have already claimed the spectrum for which they had optimized their system.

²³ As the clearest example, imagine a situation with two operational systems, one of which (System A) is designed to operate with as much spectrum as possible (but also to operate co-frequency with other NGSO systems), and the other of which (System B) is optimized to operate with $1/N$ of the allocated spectrum for NGSO FSS. Under Option I, each system would be guaranteed $1/N$ of the spectrum. The remaining NGSO FSS spectrum could be productively used by System A to provide service to customers. However, under the Commission's proposal, which would require that both parties agree on the use of the remaining spectrum, System B would control whether and how System A could employ this unused piece of spectrum, even though System B does not plan to operate in this band. The same dynamic could come to play in less obvious examples. Thus, Option I could impede fair competition among NGSO systems, and even unnecessarily threaten the commercial viability of some systems.

²⁴ In this context, “frequency diversity” refers to the agility of a system to change the frequencies used by its various communications links.

Finally, Option I could create conflict with sharing regimes adopted by other countries. Other administrations could adopt more spectrum-efficient solutions based upon co-frequency sharing among the systems, using any of a variety of interference mitigation techniques. A U.S. system optimized to operate in its reserved piece of spectrum without the need to mitigate interference to other NGSO systems could have difficulty operating within such a regime, and its ability to offer global services would suffer dramatically. The additional cost for the systems to be adapted to various sharing regimes could be very high. They would be forced to implement operational flexibilities to accommodate the different sharing regimes, which would not only defeat certain advantages of band segmentation, but could also thwart the Commission's objective of a technology-neutral solution.

B. Option II – Dynamic Band Segmentation

Unlike Option I, the Dynamic Band Segmentation approach of Option II would allocate the spectrum at any given time only among the operating systems. Thus, the first system would be entitled initially to use all of the allocated spectrum, and as each new entrant commences service, the number of individual spectrum assignments would increase. With the launch of each new system, each existing operator would be required to surrender use of a portion of the spectrum to which it previously had access. Priority in choosing slots would be based on the date each licensed system becomes operational.²⁵

This proposal suffers from essentially the same problems identified with respect to Option I above. While it may provide early entrants a temporary guarantee of access to greater spectrum than under Option I, it does nothing to guarantee continued

²⁵ NPRM, ¶ 26.

access to adequate spectrum as the system matures: i.e., when the need for maximum spectrum (capacity) most likely is greatest. It would also impose on operators design constraints that may not be compatible with the goals of their systems or with the underlying purpose of band segmentation. As with Option I, it would require operators to implement frequency diversity in order to: (i) benefit from more than 1/N of the spectrum and/or operate in any of the possible slots;²⁶ (ii) coordinate with other systems; and (iii) accommodate other international sharing regimes.

C. Option IV – Homogeneous Constellations

1. General Considerations

Option IV outlined by the Commission is premised on the adoption by the Commission of a single permissible NGSO constellation design, so that all of the operating systems would be homogeneous. While the use of similar orbital and transmission parameters would allow systems to operate co-frequency without suffering from in-line events, this option fails to meet numerous Commission goals in this proceeding.

Most importantly, it is not technology neutral. It would take critical business and technical decisions away from the marketplace and force the Commission to make such determinations. As noted by the Commission in the NRPM, the pending NGSO FSS applications represent a wide range of constellation designs.²⁷ Each design is

²⁶ Moreover, even though the Commission states that operating systems would have priority in choosing slots as new systems commence service, in contrast to Option I, even an early entrant may be forced to adopt a new frequency plan with each new entrant. For example, a third entrant that is using the center 1/3 of each sub-band would not only lose spectrum with the entry of the fourth system, but would have to migrate its operations up or down in frequency at the same time.

²⁷ NPRM, ¶ 37.

unique and optimized for specific requirements dictated by the operator's goals for the system. A constellation design is the result of many trade-offs involving technology availability, cost targets, service and performance requirements, as well as business plan objectives. No matter which design was selected by the Commission, the inescapable result of such a selection would be to render completely worthless the business plans of most of the other applicants.

Furthermore, there is no rational criteria upon which the Commission could select a "winning" design for U.S. systems according to any of the objectives articulated in the NPRM. The selection process would need to assess the overall merits of each project, or to determine a priori the relative performances of the business plans. Even among a given class of system (i.e., LEO, MEO, HEO), there are endless variations that would lead to the need for the Commission to make arbitrary decisions that may favor one applicant over the others.

As described further below, the selection of one constellation design would constrain operators toward certain classes of services, for which the chosen constellation(s) are optimized. As a result, the operators may not be able to bring to the market innovative services that depend on features not incorporated into the chosen architecture. Moreover, existing systems would have a de facto competitive advantage over new entrants. While operating systems would benefit from an installed customer base, the new entrant would not be bringing into service any significantly different technology or service. The business opportunity of a new entrant would be very reduced, further leading to less competition among NGSO operators and less benefits for the end-user.

Finally, SkyBridge shares the Commission's concern regarding the usefulness of enforcing homogeneous design once the possibility of non-U.S. systems is taken into account.²⁸ Orbit planning of this type has been rejected on numerous occasions in the ITU-R working groups, including the U.S. delegation. Therefore, homogenous U.S. systems may be obligated to share with non-homogeneous foreign systems. Because homogeneity is a substitute for implementation of generic interference mitigation techniques, the U.S. systems could experience substantial difficulty accepting the sharing burden in the coordination process with a foreign system, putting in jeopardy their global operations. If, on the other hand, they invest in system flexibility in anticipation of such a requirement, the benefits of constellation homogeneity would be lost.

The NPRM's proposed variations on this approach would involve either: (1) adopting more than one "government-approved" constellation design, and dividing the available spectrum among the selected classes of systems; or (2) reserving some spectrum for systems that choose not to adopt the approved constellation design(s).²⁹ These solutions suffer not only from many of the problems identified above, they compound those problems by guaranteeing that many operators would not have access to the amount of spectrum needed to support their constellations and business plans. SkyBridge urges the Commission to reject such hybrid approaches.

²⁸ NPRM, ¶ 40.

²⁹ Id., ¶ 38, 39.

2. Virtual Geo Proposal

Virtual Geo proposes that the orbit design of its Virgo system be selected as part of an Option IV framework. Virtual Geo is essentially asking the Commission to place a stamp of approval on its system, from both a technical and commercial standpoint. However, its orbit suffers from a number of serious drawbacks that would dramatically impede the introduction of innovative services.³⁰ Put simply, if the Virgo system design were selected, SkyBridge would be forced to abandon most of its business objectives.³¹

For example, the Virgo satellites operate around their apogee, which is at an altitude of 28,000 km. The delay induced by operation at such an altitude would impede applications that are time-sensitive, such as Telnet-based services, telephony, video-conferencing and interactive games, which are expected to be important Internet applications in the coming years. In particular, it would make it very hard for such systems to compete with land-based systems, which do not suffer from such a delay.

Moreover, the TCP/IP-transparent architecture used by SkyBridge is not feasible with Virgo-type orbits.³² The TCP protocol assumes that only terrestrial-type latencies will be encountered by the acknowledgements that have to be sent back to the

³⁰ See SkyBridge NPRM Reply Comments at 68-70.

³¹ The same would be true under Virtual Geo's proposal to split the available spectrum between Virgo-type systems and non-Virgo-type systems. SkyBridge's capacity requirements could simply not be met with access (and shared access at that) to half of the available spectrum.

³² The SkyBridge constellation is designed to be completely compatible with terrestrial networks. From the point of view of communications protocols, the satellite link is viewed by the designers as just another terrestrial-like segment in an Internet connection.

sender for each packet of information received. High latency satellite networks therefore impede the use of standard TCP protocols. Additional techniques and protocols would have to be employed to overcome this impediment, increasing the complexity of the system as well as limiting its integration into terrestrial networks. In sum, the delay introduced by a Virgo-type orbit not only irreparably decreases the quality of some highly-interactive services, but it also increases the complexity of the system needed to support important and basic communications protocols used in even less interactive applications.

Also, the SkyBridge business plan aims at offering global services to all regions between $\pm 72^\circ$ latitude. Due to the geometry and the tracking strategies (specifically a minimum elevation angle of 35° ³³) of the Virgo constellation, its ability to adequately serve tropical regions has not been demonstrated. A systematic reduction in the quality of service to the tropics, which appears to be a consequence of this elevation angle with the Virgo orbit, would be inconsistent with the SkyBridge business plan.

The chief benefit that Virtual Geo has ascribed to its architecture is its ability to accommodate a large number of homogeneous systems. However, the number of systems that can be accommodated is not a valid metric, because it says nothing about what sorts of services these systems actually can provide, and at what cost. The total traffic capacity and cost of service is all that matters for the end-user. It has not been demonstrated that maximally-packed homogeneous Virgo constellations yield any greater capacity than maximally-packed homogeneous constellations of any other type. Nor has it been demonstrated that the Virgo-type orbit, in which satellites communicate with

³³ See ITU-R Recommendation S.1328.

customers during only a limited portion of their orbits, represents a particularly cost-effective use of satellite resources.

Indeed, the only “problem” that Virtual GEO’s proposal “solves” is a problem that does not exist. Setting aside the above-described cost, capacity and service issues that Virtual Geo leaves unresolved, the sole “virtue” of its proposal is that if all of the existing applicants were forced to redesign their constellations (and business plans), they all could be accommodated in the space/spectrum provided by the Virgo constellation model. However, as demonstrated below, all of these same applicants can be accommodated under Option III, without having to redesign their systems (and business plans). The signal “virtue” of Virtual Geo’s proposal is hypothetical at best; more likely, it is entirely illusory.³⁴

Finally, the chief interference mitigation technique used to prevent interference among multiple Virgo systems is orbital spacing. Virgo-type systems may have a very difficult time accepting their sharing burden in any coordination with non-U.S. systems that do not adopt the same orbit.³⁵

³⁴ The Commission also requested comments on the impact Virtual Geo's patents would have on applicants who may desire to implement the Virgo-type orbit. NPRM, ¶ 42. Simply put, in the event that the Virgo architecture (or any other architecture) were to be adopted by the Commission as a requirement for entry into any given band, the Commission would have to require that the intellectual property rights needed to employ that architecture be licensed by the patent-holder on a non-exclusive and royalty-free basis, as is commonly done within standards-setting bodies. It would be absurd to require a licensee to pay for the patents of an orbit that it did not want to adopt in the first place.

³⁵ LEOs and MEOs do not suffer from this problem. They inherently have some satellite diversity capability that can be used to facilitate coordination with non-homogeneous systems.

In brief, the claimed superiority of the Virgo system has not been demonstrated, and the orbit is antithetical to the business plans of many of the applicants. Each of the proposed systems has advantages and drawbacks, and none is inherently superior or more suitable according to any of the Commission's stated policy objectives in this proceeding. The Commission should maintain its commitment to its principle of “an outcome dictated by the service market,” and reject Virtual Geo's request that its constellation be afforded special treatment of any kind.

D. Option III – Avoidance of In-Line Interference Events

1. General Considerations

Option III – Avoidance of In-Line Interference Events – essentially applies the band segmentation concept of Options I and II *only* when in-line or near in-line events occur (i.e., when high interference levels occur) between satellites of two or more systems. This takes advantage of the antenna discrimination inherent in all of the proposed NGSO FSS system designs. In all other configurations (i.e., when the angular separation between the constellations is large enough to protect the receivers), the entire spectrum can remain available for use by each system. This technique therefore provides a very efficient use of the spectrum, because available bands are reduced only when high-level interference configurations occur. And when such configurations do occur, band segmentation only involves the affected satellites, maximizing the amount of spectrum that can be used at all times, and hence the capacity and economic viability of the systems.

Moreover, the technique can be applied in a completely generic manner, and does not impose significant design constraints on the various systems. As SkyBridge has explained in previously filings, while implementation of satellite diversity and

frequency diversity can allow systems to further maximize the amount of spectrum available to them during in-line events, use of such techniques is not required with Option III.³⁶ The option truly gives each licensee the freedom to operate as closely as possible to its original design.

Furthermore, the technique offers full regulatory and business certainty. The Commission need not involve itself in administration of the regime once the framework is specified. And each operator can predict the spectrum it will have available to it throughout the life of its system.

At the same time, this option encourages development among individual operators of even more efficient coordination agreements, based on the individual characteristics of their systems. Indeed, the approach closely resembles the first steps taken in crafting such agreements, and can easily be fine-tuned among parties to better meet their needs. This is in stark contrast to the other options, which place licensees in a far from optimum sharing framework, interposing numerous barriers in the path of coordination.

This option also addresses a number of the concerns expressed by the Commission in the NPRM. For example, it best prepares the U.S.-licensed systems to

³⁶ See SkyBridge Ex Partes cited in note 3 above. In the NPRM, the Commission appears to be under the impression that satellite diversity capability is required with Option III. See NPRM, ¶ 31. This is not the case. Use of satellite diversity may allow a system to continue to use the entire spectrum even when one of its satellites is in an in-line configuration with the satellite of another constellation, because it may be able to switch traffic to another satellite that is not in such a configuration. However, even without the ability to switch traffic to another satellite, the system will still be able to use as much as half of the spectrum for the duration of the in-line event. While this may pose a constraint on the system, it is no greater of a constraint than that imposed by any other technology-neutral sharing solution (indeed, it is much less of a constraint than those imposed with Options I and II), and coordination agreements among operators may further reduce the impact of this constraint.

face different sharing regimes in different countries. It encourages systems to incorporate the ability to use mitigation techniques into their systems, because these techniques can help them to increase capacity even in the U.S. These capabilities can then be used to adapt to other sharing regimes that may be adopted by other countries. The other options, however, discourage development of such techniques, because they may be of limited use in the U.S. Indeed, band segmentation and the use of homogeneous constellations are designed specifically to avoid the need for such measures.

In sum, Option III would provide each entrant equal access to the spectrum, without requiring permanent and systematic reduction of the available spectrum to each operating NGSO FSS system, as in Options I and II. Furthermore, Option III does not require operators to make fundamental system design changes that would sacrifice their technical and business plans, as is the case with Option IV. In fact, *Option III is the only option that meets every one of the Commission's objectives summarized in Section I above.*

2. **Implementation**

The implementation of Option III has been discussed in detail in previous SkyBridge filings.³⁷ At its simplest, the approach will require each system to know only the locations of the satellites of the other systems, and to automatically confine its transmissions to assigned portion of spectrum whenever the predictable in-line events with other constellations occur.

³⁷ See SkyBridge Ex Partes cited in note 3 above. In particular, in its March 27, 2001 Ex Parte, SkyBridge provided extensive results of simulations quantifying the statistics of in-line events among the systems proposed by the applicants in this proceeding. In particular, the simulations showed that the probability of in-line events involving more than two systems will be small.

However, each operator will have the option of employing system flexibilities to optimize its operations. For example, satellite diversity may allow an operator to hand-over traffic to another satellite just before an in-line event in order to be able to continue to employ all of the spectrum. Therefore, the complexity introduced by this approach is largely a function of the efficiencies the operator hopes to achieve. An operator that does not need access to all of the spectrum all of the time can employ very simple protocols. Operators that hope to make maximum use of the spectrum will require more complex switching strategies.

The Commission asked for comment on the task of establishing "an unambiguous technical definition of in-line interference event parameters."³⁸ As SkyBridge explained in previous filings, there are many approaches that can be taken. The simplest is to select, in a somewhat arbitrary fashion, a benchmark angular separation between NGSO FSS constellations. Separation below that threshold would then constitute an in-line event. SkyBridge proposed a value of 10° for this value, because it would be large enough to ensure protection of the main-beams of the terminals, while still being sufficiently large to encourage coordination. However, SkyBridge also noted that some accommodation would have to be made to take into account the significantly different power levels of certain systems.³⁹

On the other hand, more rigorous approaches, which pre-select more optimum angular separations between the various constellations, are also possible. SkyBridge includes such a proposal in Annex I, attached hereto. This proposal takes into

³⁸ NPRM, ¶ 33.

³⁹ A limitation on the off-axis e.i.r.p. of the terminals, or an increased angular separation between certain constellations, could be employed for this purpose.

account the link budget and performance objectives of the NGSO FSS systems. In simplest terms, this approach defines an in-line event based on the threshold for synchronization loss of each link under clear sky conditions.

Under this approach, an in-line even occurs as soon as the synchronization of the victim link is lost due to interference from another system, as generated by an in-line satellite. In this way, the victim system is protected from harmful emissions from the interfering system, and the interfering system is required to protect the other system only when it creates harmful interference. At the same time, this arrangement constitutes a very “rough” coordination, which provides incentive to coordinate. Because it ensures that no link is broken, it permits systems to operate co-frequency, while encouraging operators to improve their common interference environment. As described in Annex I, computations can be performed to determine the ratio of inter-network interference to total system noise power under clear sky conditions that causes sync loss.

Furthermore, in order to balance the burden, SkyBridge proposes to verify the impact of the interfering system on the performance objectives of the victim constellation. This is to guarantee that an interfering system is not required to over-protect a system with overly-weak links. Even with low interference levels, the performance objectives of a victim link may be seriously impacted if insufficient margins are implemented. Therefore, the idea is to estimate the degradation by calculating the unavailability increase of a link.

It is therefore necessary to establish a level of unavailability increase that is considered acceptable. SkyBridge proposes to look to ITU-R Recommendation S.1323 and use its associated value of 10%.

A series of trial and error simulations will determine which angular separation generates the 10% unavailability increase. Further details are provided in Annex I.

It should be noted that this method is based directly on prior work by various ITU-R study groups. During the last study period, a very detailed method for such computation was developed for the NGSO/GSO case, and employed by WRC-2000. A methodology related to the I/N levels that generate sync loss appears in a Draft New Recommendation proposed for adoption at the next Study Group 4 meeting. And, as mentioned above, the value of 10% is taken from the allocation of interference from NGSO systems in recommends 3.1 of ITU-R Recommendation S.1323.

III. EARTH STATION LICENSING

A. Blanket Licensing of User Earth Stations

SkyBridge agrees with the Commission's proposal to adopt blanket licensing of user earth stations in the Ku-band, which will be ubiquitously deployed in specific frequency bands authorized for that purpose by the Commission.⁴⁰ This provides the most practical and efficient way to regulate the earth stations involved, and is entirely consistent with the Commission's regulations in analogous contexts.⁴¹

⁴⁰ NPRM, ¶ 46.

⁴¹ SkyBridge does have a concern, however, with the specific rule proposed by the Commission, 47 C.F.R. § 25.115(f). The proposal contains a sentence stating that "[e]ach application for a blanket license under this section shall include the information described in § 25.146." However, because Section 25.146 is a broad provision covering a wide variety of topics outside the scope of the user transceivers addressed in Section 25.115(f), it is entirely unclear what "information" is being referred to. SkyBridge recognizes that a similar sentence appears in provisions governing analogous satellite services, but always in reference to rules related directly to the technical requirements for the blanket-licensed transceivers.

B. NGSO FSS User Earth Station Antenna Patterns

SkyBridge agrees with the Commission's tentative conclusion that a reference antenna pattern for NGSO FSS user earth stations is not necessary.⁴²

C. NGSO FSS Earth Station Off-Axis e.i.r.p. Limits

On the other hand, SkyBridge does not agree with the Commission's proposal not to mandate off-axis equivalent isotropically radiated power ("e.i.r.p.") limits for NGSO FSS earth stations.⁴³ The Commission appears to base this decision on its earlier decision not to impose such limits on GSO FSS earth stations. However, as SkyBridge has demonstrated, that decision conflicts with international agreements to which the U.S. was a party.⁴⁴ Because the Commission's rules do not already provide limitations on GSO FSS earth station emissions equivalent to those established at WRC-2000, the Commission should apply the WRC-2000 off-axis e.i.r.p. limits and accompanying regulations (such as grandfather provisions) to GSO FSS earth stations. And, as SkyBridge has urged on prior occasions, these same limits should apply equally to NGSO FSS earth stations. No party has provided any evidence in this proceeding that the limits would be in any way burdensome to any NGSO FSS applicant, and they

⁴² NPRM, ¶ 48. SkyBridge has previously advocated adoption of a relaxed pattern that takes into account the unique characteristics of small NGSO FSS user terminals, instead of the tighter patterns often applied to earth stations in other Commission rules. See, e.g., SkyBridge NPRM Comments at 91; SkyBridge NPRM Reply Comments at 73. If the Commission changes its tentative decision and decides to adopt a pattern for user terminals, SkyBridge urges the Commission to take into account the technical considerations SkyBridge has outlined in these prior pleadings.

⁴³ NPRM, ¶ 49.

⁴⁴ SkyBridge Petition for Reconsideration at 43-45.

provide important certainty to designers of other NGSO FSS systems regarding the interference environment that will be created by multiple systems in the band.

IV. SERVICE RULES

A. Coverage Requirement

SkyBridge fully supports the Commission's proposal to apply to NGSO FSS systems in the Ku-band the same geographic coverage requirements that it applies to other NGSO satellite services intended to provide global coverage.⁴⁵ This will further the creation of a seamless, global telecommunications network. Indeed, the primary reason WRC-97 decided to facilitate NGSO FSS entry into the Ku-band was to ensure development of truly global services that would extend new telecommunications technologies to all the world's inhabitants.⁴⁶ While furthering the intent of the ITU, the proposed coverage requirement will also benefit the American public by: (1) ensuring provision of service to all corners of the United States, consistent with the mandate of Section 706 of the Telecommunications Act of 1996;⁴⁷ and (2) ensuring access to the U.S. market for commercial users and private citizens throughout the rest of the world.

B. Financial Qualifications

While SkyBridge has previously advocated the need for strict financial qualifications in this proceeding, adoption of a sharing regime based on avoidance of in-line interference events (Option III) would reduce the need for such regulatory measures. This is because all of the systems will be accommodated in the available spectrum, in a

⁴⁵ NPRM, ¶ 51.

⁴⁶ See SkyBridge NPRM Comments at 104-105.

⁴⁷ Pub. L. No. 104-104, 110 Stat. 56 (1996); 47 U.S.C.A. § 157.

manner designed to ensure that the deployment of any given system will not depend on the extent to which other parties are ready, willing and able to proceed.⁴⁸

This is not necessarily the case with the other sharing methods proposed by the Commission. Options I and II allow applicants to warehouse their rights for spectrum indefinitely, leaving the operating systems with unending uncertainty about spectrum availability. With Option IV, the "model" system may never even launch, thwarting the entire basis of the sharing plan. If the Commission adopts any of these regimes, it should impose strict financial standards consistent with those it has imposed in analogous contexts, such as in the Big LEO proceeding.⁴⁹

C. **Implementation Milestones**

The considerations noted above with respect to financial qualifications apply to some extent to the need for implementation milestones, at least vis-à-vis the NGSO applicants themselves. In other words, if Option III is implemented, delays in the build-out of one system will not adversely affect the build-out and operation of other systems.

However, SkyBridge has long supported milestones as necessary to ensure that the ultimate usage of the band is ascertained early in the deployment process. This will permit those operators ready, willing and able to put the spectrum to use to do so without lingering uncertainties caused by applicants that chose to sit on their rights.

SkyBridge would support rules and timelines consistent with those already applied by the Commission in analogous contexts, including those proposed in Appendix

⁴⁸ See SkyBridge NPRM Comments at 84.

⁴⁹ See SkyBridge NPRM Comments at 105-106; NPRM Reply Comments at 84-85.

B of the NPRM. However, the NPRM itself proposes a more interesting approach, i.e., tying the milestones to the ITU "bringing into use" rules.⁵⁰ As highlighted by the Commission, the ITU already oversees a system that functions to ensure that operators that do not proceed to expeditiously build-out their systems do not impede the progress of other systems seeking to use the same spectrum and/or orbital resources. Much regulatory simplification could be achieved if the U.S. rules were tied to the ITU timelines. In fact, if this is not the case, either the U.S. or ITU rules become irrelevant, because the licensee will need to follow whichever regime is the most strict. SkyBridge would therefore support rules conforming to the relevant ITU requirements.

D. Demonstration of Compliance with Aggregate EPFD_{down} Limits

SkyBridge agrees with the Commission's observation that "there are many regulatory difficulties in verifying compliance with the aggregate limits."⁵¹ SkyBridge therefore agrees with the Commission's decision in the Report & Order "not to require a demonstration of NGSO FSS compliance with the aggregate limits" at this time.⁵²

However, as the Commission noted, working groups within the ITU-R are currently developing methodologies that may prove helpful in this regard. SkyBridge has confidence in this effort, and will comply with the outcome. For this reason, SkyBridge supports the Commission's proposal to address the issue regarding NGSO FSS licensee

⁵⁰ NPRM, ¶ 57.

⁵¹ NPRM, ¶ 59.

⁵² NPRM, ¶ 59.

demonstration of aggregate EPFD_{down} limits when the ITU has completed its work on these methodologies.⁵³

Importantly, due to the mathematical relationship between the single entry and the aggregate limits, there can be no concern about violation of the aggregate limits until more than three systems are operating. As the Commission recognized, this will take "a good deal of time," which diminishes the urgency of arriving at a regulatory solution at this juncture.⁵⁴ In the meantime, the Commission could simply include in each license a statement putting the licensees on notice that, once a fourth system seeks to commence operations, the Commission may require all of the operating licensees to collectively demonstrate compliance using the most relevant ITU-R methodology approved at that point in time.

E. Demonstration of Compliance with Single-Entry EPFD_{down} Limits

SkyBridge is perplexed by the appearance in Appendix B of the instant NPRM of a proposed rule -- Section 25.146(h)(3) -- requiring each NGSO FSS applicant to provide a detailed list of technical information, including proprietary operational parameters, as well as a "sufficient technical showing" that its system meets the EPFD_{down} limits in Section 25.208. Rules for assessing compliance with these limits were already adopted in the Report & Order in this proceeding, with the result that Sections 25.146(a)-(e) already dictate in great detail the comprehensive showing each applicant will be required to submit to the Commission to demonstrate compliance with these limits. The new proposed rule was not discussed or even mentioned in the text of the

⁵³ NPRM, ¶ 60, n.86.

⁵⁴ Id., ¶ 61.

NPRM, and appears to be either an oversight, or an attempt to re-open controversial issues already dealt with by the Commission. In any case, it suffers from a number of serious flaws.

The proposed rule requires "a sufficient technical showing to demonstrate that the proposed non-geostationary satellite orbit system meets the power-flux density limits contained in Section 25.208," without providing any indication of what a "sufficient technical showing" would entail. As the Commission knows full well, exactly what ought to be required in such a showing has been the focus of intense international and domestic debate. In the Report & Order, the Commission adopted a detailed specification for this showing, based in part on the international consensus on these issues. The Commission's new proposed rule flatly contradicts this effort, by introducing a vague requirement that is open to numerous competing interpretations.

Furthermore, as SkyBridge has explained on numerous occasions, "NGSO hand-over and satellite switching strategies," which would be required to be disclosed under the proposed rule, both: (1) change with time as traffic patterns evolve; and (2) convey commercially-proprietary information. For these reasons, the international community has worked diligently to develop disclosure requirements and compliance protocols that do not require disclosure of this information.⁵⁵ The Commission's proposed rule ignores this concern.⁵⁶

⁵⁵ In its Petition for Reconsideration of certain of the rules in the Report & Order, SkyBridge recognized that disclosure of such information may be necessary and appropriate in order to resolve a dispute regarding compliance with the operational-types limits. However, SkyBridge urged the Commission to grant confidential treatment to any such submissions. See SkyBridge Petition for Reconsideration at 42.

⁵⁶ SkyBridge clearly has no objection to provision of AP3 and AP4 information, or any of the information sought under any ITU requirements or recommendations, such as

In view of the detailed requirements already contained in Sections 25.146(a)-(e), SkyBridge is strongly opposed to proposed Section 25.146(h)(3), and urges the Commission to abandon it.

F. International Coordination

The Commission seeks comment on its proposal to coordinate U.S. systems internationally "consistent with our domestic frequency plans," as it did with the Big LEO systems.⁵⁷ In the case of the Big LEO systems, however, the Commission had adopted a detailed frequency plan that had an impact on the international operations of the systems. If the Commission adopts Option III in this proceeding, this will not be the case here. In this case, SkyBridge is concerned that the Commission's proposal could preclude U.S.-licensed systems from taking advantage of spectrum that is available in other countries, but that is not available here due purely to domestic considerations.

For example, there is no reason why U.S. systems should not be coordinated to use the 13.15-13.2125 GHz band in other countries, even though the Commission declined, in the Report & Order, to permit NGSO FSS operation in this band in the U.S. in order to protect certain terrestrial services.⁵⁸ Permitting systems to take advantage of opportunities that may exist in other regions and countries will not cause a

the input data to the ITU-R validation software, or ITU-R Recommendation S.1328. However, all of this information is either already required under other Commission rules, or will be publicly available through the ITU without the need for additional Commission requirements.

⁵⁷ NPRM, ¶ 64.

⁵⁸ SkyBridge has petitioned the Commission for reconsideration of this decision, based on the considerable opportunities for sharing between these services in the band. See SkyBridge Petition for Reconsideration at 17-25.

"substantial delay in the implementation of service,"⁵⁹ and will permit U.S. systems to deploy the most effective and efficient systems possible. In fact, failure to permit U.S.-licensed systems to take advantage of such opportunities will disadvantage them vis-à-vis foreign-licensed systems.

G. System License and License Terms

SkyBridge supports the Commission's proposals to provide a blanket license for all technically identical satellites, and adopt a 10-year license term, running from the date on which the first space station in the system begins transmissions.⁶⁰ SkyBridge also agrees with the Commission that the current filing window for system replacement applications is appropriate, and should be applied to Ku-band NGSO FSS systems.

H. Regulatory Classification

SkyBridge supports the Commission's proposal to treat operators of NGSO FSS systems in the Ku-band as non-common carriers, consistent with the Commission's DISCO I Order⁶¹ and the proposals of all of the applicants in this processing round.⁶²

⁵⁹ NPRM, ¶ 64.

⁶⁰ Id., ¶ 54.

⁶¹ Amendment to the Commission's Regulatory Policies Governing Domestic Fixed Satellites and Separate International Systems, 11 FCC Rcd 2429, 2436 (1996) ("DISCO I Order").

⁶² NPRM, ¶ 55.

I. Reporting Requirements

SkyBridge supports the Commission's proposal to require annual reports from licensees describing the status of satellite construction and anticipated launch dates, including any major delays or problems encountered.⁶³ SkyBridge also agrees with the Commission's proposal not to require reports of satellite outages, because with NGSO FSS systems, such outages are not likely to be used to warehouse spectrum.

J. Orbital Debris Mitigation

SkyBridge shares the Commission's concerns regarding orbital debris, and would support the extension to Ku-band NGSO FSS licensees of the current requirement that 2 GHz MSS applicants disclose their orbital debris mitigation plans. Furthermore, the Commission notes in the NPRM that it plans to commence a separate rulemaking proposing to adopt filing requirements on these issues for all Commission-licensed satellite services, and SkyBridge would support application to Ku-band NGSO FSS systems of any requirements adopted in that rulemaking that are generally applicable to other satellite systems.⁶⁴

K. Sale of License

SkyBridge supports the Commission's proposed rule that would prohibit any Ku-band NGSO FSS licensee from selling a bare license for profit.⁶⁵ This provision would discourage speculation and prevent unjust enrichment of those who do not implement their proposed systems. This rule is consistent with those applicable to

⁶³ NPRM, ¶ 58.

⁶⁴ Id., ¶ 66.

⁶⁵ Id., ¶ 68.

Commission licensees in analogous contexts, and there is no reason not to extend the prohibition to new NGSO FSS licensees.

CONCLUSION

In order to foster provision of innovative satellite broadband services to all Americans, the Commission should quickly license the applicants in the current Ku-band NGSO FSS processing round. This should be accomplished in a manner that provides business and regulatory certainty that all licensees will enjoy equal opportunities to build and launch their systems, as designed in accordance with their individual business plans, with access to sufficient spectrum for broadband applications. Of the Commission's proposals in the NPRM, only Option III meets these important goals, and SkyBridge urges the Commission to proceed expeditiously to implement that approach.

Respectfully submitted,

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July 6, 2001

Annex I

Defining an In-Line Event: The I/N Approach

As described in the accompanying comments, Option III features several characteristics that make it an ideal framework for a default coordination procedure between NGSO systems. This option is based on avoidance of interference during in-line events between satellites of different constellations. Below, SkyBridge outlines a method for defining an in-line event. It is based on the RF characteristics of the systems, as well as their performances objectives. This approach builds on the work performed within the ITU-R for the protection of GSO systems, in order to establish a parallel between the two sharing environments.

1. Synchronization losses

Sensitivity to synchronization loss due to rain is a problem common to GSO and NGSO networks. All the proposed NGSO systems in the Ku-band have a digital air interface. The observation of the achievements obtained in optimizing digital waveforms shows that for such types of transmissions, availability and synchronization loss are almost equivalent. NGSO/NGSO sharing will increase the probability of sync loss in all rain zones.

Loss of synchronization can be extremely disruptive to certain services that, under current circumstances, are adequately provided over satellite networks. A simple I/N calculation can be performed to demonstrate whether or not an NGSO earth station, receiving a given rain rate, is susceptible to NGSO-induced sync loss. The calculation depends on the received carrier-to-noise ratio $(C/N)_{\text{sync loss}} = C/(N+I)$ at which sync loss occurs. $(C/N)_{\text{sync loss}}$ is typically in the range of 1 to about 4 dB below the $(C/N)_{\text{required}}$ needed for the minimum BER performance objective desired for the link. A link where $\Delta(C/N) = ((C/N)_{\text{required}} - (C/N)_{\text{sync loss}}) = 1$ dB is representative of 1/2 rate coding, while $\Delta(C/N) = 3$ dB is representative of 3/4 rate coding.

Table 1 provides typical modulation and sync loss information for systems with data rates less than 34 Mbits/s, as adopted by ITU-R:

TABLE 1

Modulation and coding	C/(N+I) (dB)
QPSK rate 7/8	6.0
QPSK rate ¾	5.3
QPSK rate ½	3.5
8-PSK	8.1
16-QAM	11.0

Generally, the amount of carrier-to-noise degradation to cause sync loss is known (for a given link). This information can be used to calculate the interference levels that will cause a harmful loss of synchronisation for NGSO links.

2. Definitions

This section introduces the notation used in the rest of the presentation:

- The performance degradation of a communications link can be expressed in terms of an equivalent increase in the system noise temperature as compared to a link without the degrading influence. That relationship can be expressed as:

$$\text{Degradation (dB)} = 10\text{Log}((T+\Delta T_I)/T)$$

- T = system noise temperature (°Kelvin, includes noise from all known sources)
- ΔT_I = system noise temperature increase due to added interference source (°Kelvin)
- M_R = clear sky rain margin (dB)
- $\Delta(C/N)$ = dB decrease in threshold C/N from the lowest performance objective to the sync loss level

3. I/N threshold for synchronization loss

Under clear sky conditions, the relationship between the normal operating system noise temperature, the additional rain margin and the noise temperature increase due to interference which might cause sync loss is given by equation (1) as follows:

$$10\text{Log}((T+\Delta T_I)/T) = M_R \text{ (dB)} + \Delta(C/N)\text{(dB)} \quad (1)$$

The level of received interference power that would cause sync loss can be determined by solving for ΔT_I in equation (1). That resulting interference level allows the determination of the epfd level that would cause sync loss to occur. Accordingly, the noise temperature increase due to interference that would cause sync loss is given in equation (2) as follows:

$$\Delta T_I / T = (10^{(M_R + \Delta(C/N))/10} - 1) \quad (2)$$

The increase in noise temperature $(\Delta T_I) / T$ due to interference can then be used to calculate the resulting (I_T / N) (dB) increase with equation (3) as follows:

$$(I_T / N)_{\text{threshold}}\text{(dB)} = \Delta T_I / T = (10^{(M_R + \Delta(C/N))/10} - 1) \quad (3)$$

Whenever the I/N level generated by the interfering NGSO system into the victim NGSO system exceeds $(I_T / N)_{\text{threshold}}$, the interference becomes harmful. It is proposed here to adopt this threshold as the definition of the in-line event.

4. Use of the avoidance of in-line events

As can be seen, this definition of the in-line event is system-dependant. However, a very sensitive system with very low margin and a high synchronisation threshold will have a low $(I_T/N)_{\text{threshold}}$, which implies a wider angular separation.

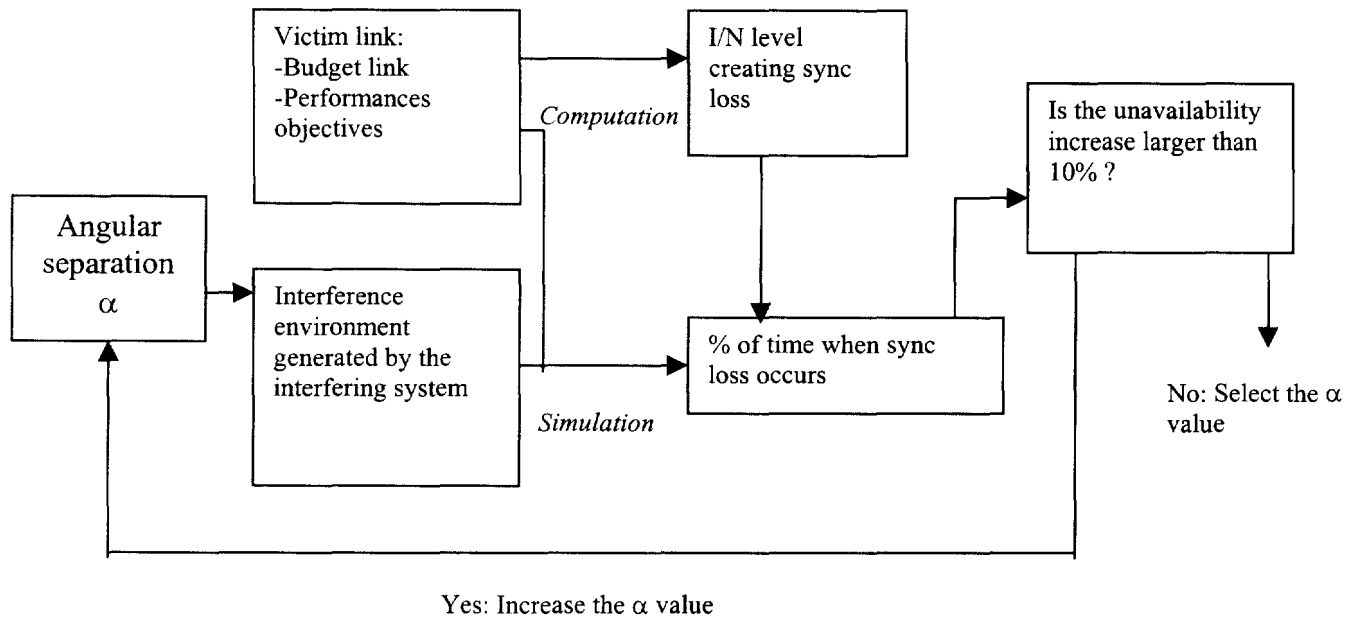
This, of course, would not be correlated with the associated poor performances of such systems with very low operating margin. To compensate for this it is proposed to apply, in association with the $(I_T/N)_{\text{threshold}}$ definition of the in-line event, *recommends* 3.1 of ITU-R Recommendation S.1323. This recommends allocates 10% of availability reduction to NGSO systems.

In practice, a full simulation of the two concerned NGSO systems would be performed, calculating the I/N distribution of interfering NGSO system A over victim NGSO system B. Whenever the percentage of time I/N exceeds $(I_T/N)_{\text{threshold}}$ is lower then 10% of the unavailability due to rain, the system B wouldn't need any protection during in-line events, no coordination would then be required, system A respecting the coordination thresholds of system B.

Should the percentage of time exceed 10% of the unavailability, the avoidance of the in-line event would then apply as a default coordination, although actual coordination could achieve better results between the two operators.

The systems described at the beginning of this section, with very low margins, would have higher unavailabilities, and therefore could cope with more interference from other NGSO (10% of a bigger time percentage).

The figure below illustrates the process to determine the angular separation between two constellations¹:



5. Simulations considerations

As pointed out in a recent SkyBridge ex-parte, there is always a certain amount of arbitrary decisions in any coordination process. For the proposed methodology, the main arbitrary aspect comes from the fact that simulations of NGSO systems can implicate use of a large number of elements, such as the terminal density or the tracking strategy. SkyBridge is of the opinion that the simulations here, while conservative, should represent typical operations of systems. Thus, it is proposed to model the terminal grid to have one full-time and full-power terminal per centre of beam of the interfering satellites. Additionally, an interfering system terminal must be co-located with the victim earth station. The “best elevation” tracking strategy is also a fairly representative tracking strategy.

¹ It should be noted that the computation must be done both ways (i.e. with a system as both victim and interfering). The final value is the larger of the two angles obtained.